

Example 3: Preparation of Oligonucleotide-Modified Gold Nanoparticles

Gold colloids (13 nm diameter) were prepared as described in Example 1. Thiol-oligonucleotides [HS(CH₂)₆OP(O)(O')-oligonucleotide] were also prepared as described in Example 1.

The method of attaching thiol-oligonucleotides to gold nanoparticles described in Example 1 was found not to produce satisfactory results in some cases. In particular, when long oligonucleotides were used, the oligonucleotide-colloid conjugates were not stable in the presence of a large excess of high molecular weight salmon sperm DNA used as model for the background DNA that would normally be present in a diagnostic system. Longer exposure of the colloids to the thiol-oligonucleotides produced oligonucleotide-colloid conjugates that were stable to salmon sperm DNA, but the resulting conjugates failed to hybridize satisfactorily. Further experimentation led to the following procedure for attaching thiol-oligonucleotides of any length to gold colloids so that the conjugates are stable to high molecular weight DNA and hybridize satisfactorily.

A 1 mL solution of the gold colloids (17nM) in water was mixed with excess (3.68 μM) thiol-oligonucleotide (28 bases in length) in water, and the mixture was allowed to stand for 12-24 hours at room temperature. Then, 100 μL of a 0.1 M sodium hydrogen phosphate buffer, pH 7.0, and 100 μL of 1.0 M NaCl were premixed and added. After 10 minutes, 10 μL of 1% aqueous NaN₃ were added, and the mixture was allowed to stand for an additional 40 hours. This "aging" step was designed to increase the surface coverage by the thiol-oligonucleotides and to displace oligonucleotide bases from the gold surface. Somewhat cleaner, better defined red spots in subsequent assays were obtained if the solution was frozen in a dry-ice bath after the 40-hour incubation and then thawed at room temperature. Either way, the solution was next centrifuged at 14,000 rpm in an Eppendorf Centrifuge 5414 for about 15 minutes to give a very pale pink supernatant containing most of the oligonucleotide (as indicated by the absorbance at 260 nm) along with 7-10% of the colloidal gold (as indicated by the absorbance at 520 nm), and a compact, dark, gelatinous residue at the bottom of the tube. The supernatant was removed, and the residue was

resuspended in about 200 μ L of buffer (10 mM phosphate, 0.1 M NaCl) and recentrifuged. After removal of the supernatant solution, the residue was taken up in 1.0 mL of buffer (10 mM phosphate, 0.1 M NaCl) and 10 μ L of a 1% aqueous solution of NaN₃. Dissolution was assisted by drawing the solution into, and expelling it from, a pipette several times. The resulting red master solution was stable (*i.e.*, remained red and did not aggregate) on standing for months at room temperature, on spotting on silica thin-layer chromatography (TLC) plates (see Example 4), and on addition to 2 M NaCl, 10 mM MgCl₂, or solutions containing high concentrations of salmon sperm DNA.

Example 4: Acceleration Of Hybridization of Nanoparticle-Oligonucleotide Conjugates

The oligonucleotide-gold colloid conjugates I and II illustrated in Figure 11 were prepared as described in Example 3. The hybridization of these two conjugates was extremely slow. In particular, mixing samples of conjugates I and II in aqueous 0.1 M NaCl or in 10 mM MgCl₂ plus 0.1 M NaCl and allowing the mixture to stand at room temperature for a day produced little or no color change.

Two ways were found to improve hybridization. First, faster results were obtained by freezing the mixture of conjugates I and II (each 15 nM contained in a solution of 0.1 M NaCl) in a dry ice-isopropyl alcohol bath for 5 minutes and then thawing the mixture at room temperature. The thawed solution exhibited a bluish color. When 1 μ L of the solution was spotted on a standard C-18 TLC silica plate (Alltech Associates), a strong blue color was seen immediately. The hybridization and consequent color change caused by the freeze-thawing procedure were reversible. On heating the hybridized solution to 80°C, the solution turned red and produced a pink spot on a TLC plate. Subsequent freezing and thawing returned the system to the (blue) hybridized state (both solution and spot on a C-18 TLC plate). In a similar experiment in which the solution was not refrozen, the spot obtained on the C-18 TLC plate was pink.

A second way to obtain faster results is to warm the conjugates and target. For instance, in another experiment, oligonucleotide-gold colloid conjugates and an

oligonucleotide target sequence in a 0.1 M NaCl solution were warmed rapidly to 65°C and allowed to cool to room temperature over a period of 20 minutes. On spotting on a C-18 silica plate and drying, a blue spot indicative of hybridization was obtained. In contrast, incubation of the conjugates and target at room temperature for an hour in 0.1 M NaCl solution did not produce a blue color indicative of hybridization. Hybridization is more rapid
5 in 0.3 M NaCl.

Example 5: Assays Using Nanoparticle-Oligonucleotide Conjugates

The oligonucleotide-gold colloid conjugates 1 and 2 illustrated in Figures 12A-F were prepared as described in Example 3, and the oligonucleotide target 3 illustrated in Figure 12A was prepared as described in Example 2. Mismatched and deletion targets 4, 5, 6, and 7 were purchased from the Northwestern University Biotechnology Facility, Chicago, IL. These oligonucleotides were synthesized on a 40 nmol scale and purified on an reverse phase C18 cartridge (OPC). Their purity was determined by performing ion exchange HPLC.
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Selective hybridization was achieved by heating rapidly and then cooling rapidly to the stringent temperature. For example, hybridization was carried out in 100 μ L of 0.1 M NaCl plus 5 mM MgCl₂ containing 15 nM of each oligonucleotide-colloid conjugate 1 and 2, and 3 nanomoles of target oligonucleotide 3, 4, 5, 6, or 7, heating to 74°C, cooling to the temperatures indicated in Table 1 below, and incubating the mixture at this temperature for 10 minutes. A 3 μ L sample of each reaction mixture was then spotted on a C-18 TLC silica plate. On drying (5 minutes), a strong blue color appeared if hybridization had taken place.
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The results are presented in Table 1 below. Pink spots signify a negative test (*i.e.*, that the nanoparticles were not brought together by hybridization), and blue spots signify a positive test (*i.e.*, that the nanoparticles were brought into proximity due to hybridization involving both of the oligonucleotide-colloid conjugates).
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